absorption by carriers in the light guide layers **101a** and **101b** decreases, making it possible to increase slope efficiency of the semiconductor laser device.

[0053] FIG. **5** is a diagram illustrating light confinement of the active layer when the position of the active layer is changed in the light guide layer when there is no low-refractive-index layer. While keeping the sum d of layer thickness of the light guide layer **3** constant at 1200 nm, the layer thickness do of the n-side AlGaAs light guide layer **9** and the layer thickness dp of the p-side AlGaAs light guide layer **10** are changed. It is observed that the light confinement of the active layer **11** is largest (dn=dp=600 nm) when the active layer **11** is located at the center of the light guide layer **3** and monotonously decreases as the active layer **11** is brought closer to the p-type AlGaAs cladding layer **4** or n-type AlGaAs cladding layer **2**, and has a symmetric shape with respect to the center of the light guide layer **3**.

[0054] FIG. **6** is a diagram illustrating the light confinement of the active layer when the position of the active layer of the semiconductor laser device according to the first embodiment of the present invention is changed in the light guide layer. A single-dot dashed line shows a case where a composition ratio x of Al of the n-type AlGaAs low-refractive-index layer **12** is 0.30, the layer thickness d1 is 100 nm, a solid line shows a case where x=0.35 and d1=200 nm, and a two-dot dashed line shows a case where the x=0.35 and d1=400 nm. A broken line shows a case where there is no n-type AlGaAs low-refractive-index layer **12**. Note that refractive indexes of AlGaAs having composition ratios of 0.30 and 0.35 with respect to light having a wavelength of 915 nm are 3.3624 and 3.3315 respectively.

[0055] It is observed from FIG. **6** that as the Al composition ratio x of the n-type AlGaAs low-refractive-index layer **12** increases and the refractive index nl decreases, and as the layer thickness d1 of the n-type AlGaAs low-refractive-index layer **12** increases, the peak position of light confinement is displaced toward the p-type AlGaAs cladding layer **4** side and the value of light confinement at the peak position increases. Based on this, the operation of the n-type AlGaAs low-refractive-index layer **12** can be considered in the same way as light confinement. That is, as the difference in refractive index from the cladding layer increases, and the layer thickness d1 of the n-type AlGaAs low-refractive-index layer **12** increases, the peak position of light confinement can be displaced toward the p-type AlGaAs cladding layer **4** side and the value of light confinement at the peak position can be increased, and it is thereby possible to determine the amount of

$$\sqrt{n_c^2 - n_l^2}d_l$$

as an index when the n-type AlGaAs low-refractive-index layer **12** is inserted. When the low-refractive-index layer is inserted into the n-type cladding layer side and the p-type cladding layer side, the magnitude of the value will be defined hereinafter.

[0056] In the present embodiment, the active layer **11** is disposed at a position where the light confinement of the active layer **11** becomes smaller compared to a case with a symmetric structure in which the active layer **11** is disposed at the center of the light guide layer **3** while there is no n-type AlGaAs low-refractive-index layer **12**. For example, in a case where the Al composition ratio x of the n-type AlGaAs low-refractive-index layer **12** is 0.35 and the layer thickness d1 is 200 nm, if the active layer **11** is disposed

from point A (+174 nm) where the light confinement value becomes the same as that at the center of the light guide layer **3** of the symmetric structure to a position of an end of the p-side light guide layer (+600 nm), it is possible to reduce light absorption by carriers in the light guide layer **3** compared to the symmetric structure and the conventional asymmetric structure, and thereby increase the slope efficiency. As a result, it is possible to reduce an operating current during high output power and improve the power conversion efficiency.

[0057] FIG. **7** is a diagram illustrating a P-I characteristic of the semiconductor laser device according to the first embodiment of the present invention. A solid line shows a characteristic of the first embodiment, a broken line shows a characteristic of the symmetric structure, and a single-dot dashed line shows a characteristic of the conventional asymmetric structure. A threshold current (I_{th}^P) of the first embodiment is higher than a threshold current (I_{th}^s) of the symmetric structure and a threshold current (I_{th}^c) of the conventional asymmetric structure. However, slope efficiency (η_s^P) can be made much higher than the value (η_s^s) of the symmetric structure and the value (η_s^c) of the conventional asymmetric structure. As a result, in a region where the operating current is greater than $(\eta_s^P I_{th}^P - \eta_s^s I_{th}^s)/(\eta_s^P - \eta_s^s)$, the operating current can be made lower than that in the symmetric structure. Furthermore, in a region where the operating current is greater than $(\eta_s^P I_{th}^P - \eta_s^c I_{th}^c)/(\eta_s^P - \eta_s^c)$, the operating current can be made lower than that in the conventional asymmetric structure. Therefore, the semiconductor laser device according to the present embodiment can reduce the operating current during large output power, and can thereby increase power conversion efficiency (η_e) defined by optical output power (Pop) with respect to injected power (Vop·Iop).

Second Embodiment

[0058] FIG. **8** is a cross-sectional view illustrating a semiconductor laser device according to a second embodiment of the present invention. The light guide layer **3** of the present embodiment includes a first light guide layer **13** formed on the n-type AlGaAs cladding layer **2**, and second light guide layers **14** and **15** formed on the first light guide layer **13**. The active layer **11** is formed between the second light guide layers **14** and **15**. The first light guide layer **13** is AlGaAs having an Al composition ratio of 0.210. The second light guide layers **14** and **15** are AlGaAs having the same Al composition ratio of 0.190. The sum of a layer thickness dn2 of the second light guide layer **14** and a layer thickness dp of the second light guide layer **15** is 450 nm and is smaller than a layer thickness 750 nm of the first light guide layer **13**.

[0059] The sum of layer thicknesses of the first light guide layer **13** and the second light guide layers **14** and **15** is 1200 nm. Note that the refractive index of AlGaAs having an Al composition ratio of 0.190 with respect to light having a wavelength of 915 nm is 3.4327. There is no n-type AlGaAs low-refractive-index layer **12**. The rest of the configuration is similar to that of the first embodiment.

[0060] FIG. **9** is a diagram illustrating a refractive index distribution along a crystal growing direction in the vicinity of the active layer of the semiconductor laser device according to the second embodiment of the present invention. A refractive index ng2 of the second light guide layers **14** and **15** is higher than a refractive index ng of the first light guide layer **13**. For this reason, a normalized frequency v functions